Master classes and laboratory works concept development

The main goal of master classes is to get students and PhD students acquainted with modern methods of experiments conduction and data analysis. The master classes concept is based on the experience of similar activity (A. Romaniouk: Large gas detector systems at LHC, the ATLAS TRT Detector) at CERN "Excellence in Detectors and Instrumentation Technologies" school for PhD students and postdocs in 2011. All 36 master classes at this school were graded by the participants; the master classes on the gas systems at LHC received a highest grade. It made it easier to understand what particular knowledge experimental physics experts were still lacking for. Department 40 is preparing the master classes, which extend the above-mentioned activity at the CERN school. Besides, these master classes are concluded by a laboratory work with physics analysis. Students will be asked to perform a physics analysis of real events with Z, W and Higgs bosons production. Light versions of experimental data analysis software will be used for this activity. Master classes within the ATLAS experiments use the same analysis software.

Modern experiment consists of large number of complex systems. The only way to get students acquainted and prepared to work at CERN is through remote work sessions. Students and PhD students, willing to take part in the ATLAS experiment, will participate online in the experiment conduction and TRT data quality control. It will create a possibility for students to participate in the experiment and to learn under the same conditions as in the real experiment in real time. This activity may be carried out only during active data taking periods. Later on, laboratory works will be conducted on new particle detectors as well.

Main goal of these master classes is to guide students through equipment and physical operational principles of a detector element (thin-wall proportional drift chamber), studying its response to ionizing particles and electronics operation, analyzing and diagnosing real detector with 350000 channels, and, finally, obtaining physics result. Nowadays master classes consist of an introductory lecture and four laboratory works. Besides, a web portal with textual information, handbooks and multimedia is being created. Laboratory works will constantly evolve.

These activities are meant for graduating students and PhD students, who have studied all instrumental and physical courses.

Introductory lecture

Experiments in high energy physics at LHC as an example

Main purpose of the introductory lecture is to introduce students to the modern tendencies of accelerator experiments, to physical problems they solve and give an idea of the detectors and their purpose. Each of the existing or planned accelerators and experiments have their own features and can use various technologies. However, basic purpose of the main units is usually the same. Thus, the review will deal with Large Hadron Collider and ATLAS experiment, where MEPhI department 40 workgroup is involved. Lecture will be focused on the issues important for the following laboratory works.

Overview

- Modern trends in the high-energy physics experiments
- Large Hadron Collider, its structure, operation principles, beams structure, timing, luminosity
- Physics problems of the LHC in proton-proton and ion-ion collisions
- 4 experiments at the LHC and their purposes
- ATLAS experiment: structure, detectors, triggers, particle identification, radiation occupancy, the problem areas and requirements for the sLHC
- TRT detector: short history of development, structure, operation principles, electron identification

Laboratory work #1

The basic principles of TRT operation

The main purpose of the laboratory work #1 is to study physical principles of the elementary cell of the TRT (Transition Radiation Tracker), to familiarize oneselves with TRT design and the purpose of the electrical chains elements. Students should measure gas gain factor in the chamber, estimate electronics noise level and define an optimal threshold. Students will also be acquainted with TRT electronics design and the purpose of its elements.

Overview

- Drift tube and its design
- Ionization, ionization loss in the tube, transition radiation
- Gas gain, the signal before and after amplifier
- Electronics noise, discriminating threshold
- Physical characteristics depending on thresholds (spatial resolution, electrons separation)
- Working with drift tube: optimal gas gain and threshold determination in eV, eV translation into equivalent number of electrons, calibration in mV
- The design of input electrical connections
- Characteristics and importance of each element
- Principle circuit of FE electronics, the purpose and operation of its basic elements
- What is transferred to a remote part of electronics
- Answers to questions

Laboratory work #2

TRT and modern monitoring methods and diagnostic tools (TRTViewer)

The main goal of the laboratory work #2 is to study the construction and functioning of the ATLAS TRT and to get some experience with modern detector monitoring tools using TRTViewer software package. Students will learn to work with TRTViewer monitoring software package. They will determine TRT noise characteristics and will test TRT prototype on cosmic rays, will get an insight into track reconstruction, timing calibration and malfunctions diagnostics.

Overview

- ATLAS TRT function and construction
- Introduction to the TRT front-end electronic principles (FE-ROD-ROS-EventBuilder)
- TRTViewer software package (short description), means of data presentation (event display, straw data, straw maps, histograms (straw click and browser))
- Timing bit pattern from the drift tube and its presentation in TRTViewer window
- Threshold scan (noises), threshold tuning, the means of noise suppressions (Validity gate)
- Operation with cosmic particles data and Fast-OR trigger
- Track reconstruction procedure, timing calibration (t_0, R-t dependence), coordinate accuracy, efficiency.
- Electrons identification principles, dependency on threshold and high voltage
- Analysis of test results and problems characterization (noise, electronics problems, high voltage problems)
- Answers to control questions, plotting

Laboratory work #3

Work with TRT in data taking mode

The main goal of the laboratory work #3 is an introduction to modern methods of conducting high-energy physics experiments, detector parameters control and monitoring its characteristics in data taking mode by the example of TRT. Students will be introduced to Data Acquisition System (DAQ) operation principles, detector systems slow control methods (DCS) and data monitoring concepts in both offline and online operation modes. Students access TRT state control system in demo mode via web interface. They process "raw" TRT data from proton-proton collisions and data saved as ROOT histograms using monitoring software (TRTViewer) available on MEPhI computers.

Overview

- Introduction to DAQ system, readout electronics and online event reconstruction
- Detector Control System: destination, operation principles, errors/failures propagation
- Significance of detector slow control parameters. Remote control
- Monitoring systems. Data representation in online mode
- TRTViewer: work with "raw" data and ROOT files obtained from various monitoring software
- TRT diagnostics. Significance of parameters under control
- Questions

Laboratory work #4

Physics events analysis concepts in the ATLAS experiment

The main goal of the laboratory work #4 is an introduction to the basic concepts of the real physics events analysis in ATLAS experiment. First part: destination and capabilities of different ATLAS detectors. Participants gain some insight into physics processes happening inside the detectors, and how to use signatures of these processes to identify various particles. Second part: experimental data analysis using ATLAS events visualization software. Participants identify final "visible" particles and select events with Z, W or Higgs bosons production. Several decay modes are considered for every of these bosons.

Overview

- ATLAS experiment setup:
  - Inner detector
  - Electromagnetic calorimeter
  - Hadronic calorimeter
  - Muon system
- Trigger systems, three trigger levels
- Particles identification methods, destination and capabilities of different detectors
- Identifying events with Z, W, Higgs bosons decays. Background events.
- Visualization and events analysis
- Reconstructing invariant mass
- Missing transverse energy
- Questions